Chapter 12
Real Options

Road Map

Part A Introduction to finance.

Part B Valuation of assets, given discount rates.

Part C Determination of risk-adjusted discount rate.

Part D Introduction to corporate finance.
  • Forwards and futures.
  • Options.
  • Real options.

Main Issues

• Strategic Options in Real Investments

• Valuation of Strategic Options
1 Options In Real Investments

In capital investment decisions, we often face situations involving strategic options. Common and important options in capital investments include:

- The option to wait before investing
- The option to make follow-on investments
- The option to abandon a project
- The option to vary output or production methods.

Two key elements in strategic options and their valuation:

1. New information arrives over time
2. Decisions can be made after receiving new information.

Example. Acid Rain. By delaying the decision, we can use new information on future costs of scrubbers and allowances.
2 Strategic Options: An Example

Example 1. UW Inc. is considering buying a copper mine:

- The mine can produce one million kilograms (kg) of copper, but only for one year, and it becomes useless after that.
- It takes one year to extract the copper, and the extraction cost is $1.8 per kilogram paid up-front, and it will increase 10% next year.
- The copper price is now $S_0 = 2$ per kilogram. The next year, it may either increase by the factor $u = 1.3$ to $2.6$, or decrease by the factor $d = 0.8$ to $1.6$ with equal probability, $p = 0.5$.
- All uncertainty about copper price is resolved next year.
- The copper price risk is completely diversifiable so that future cash flows can be discounted at the risk-free rate.
- The risk-free interest rate is 5% and constant over time.

Question: What is the value of this project at $t = 0$?
2.1 Valuation Using Naive NPV

We first evaluate this project using the naive NPV criterion.

1. Go ahead with the project (extract) now.

- The expected cashflow next year is
  \[
  \frac{2.6 + 1.6}{2} = \frac{4.2}{2} = \$2.1 \text{ (per kg.).}
  \]

- The NPV (per kg) using static DCF formula gives:
  \[
  NPV_0^{\text{static}} = -1.8 + \frac{2.1}{1.05} = \$0.2.
  \]
2. Wait one year and go ahead with the project (no matter what the price of copper may be then).

- In the “up-state”, the NPV of the project in year 1 is

\[ NPV_{1, \text{up}} = -1.98 + \frac{(2.6)(1.05)}{1.05} = 0.62. \]

- In the “down-state”, the NPV of the project in year 1 is

\[ NPV_{1, \text{down}} = -1.98 + \frac{(1.6)(1.05)}{1.05} = -0.38. \]

- The NPV now (in year 0) is

\[ NPV_0 = \frac{(NPV_{1, \text{up}} + NPV_{1, \text{down}})/2}{1.05} = \frac{(0.62 - 0.38)/2}{1.05} = 0.114. \]

Using naive NPV calculations, we would have concluded:

- Buying the mine has positive NPV.
- We should start extracting copper now.
- The NPV is \((0.2)(1,000,000) = 200,000.\)

**Question:** Is this the best we can do?
2.2 Valuation Using Sophisticated NPV

But if we wait, we would not extract copper in the down state.

Let us now redo the calculation, taking into account the flexibility in responding to new information about copper price:

- In the “up-state”, NPV of the project is
  \[
  NPV_{1,\text{up}} = -1.98 + \frac{(2.6)(1.05)}{1.05} = \$0.62.
  \]

- In the “down-state”, NPV of the project, if we extract, is
  \[
  NPV_{1,\text{down}} = -1.98 + \frac{(1.6)(1.05)}{1.05} = \$-0.38.
  \]

- Since it does not pay off to extract in the “down-state”, we would not. The NPV now (in year 0) is
  \[
  NPV_0 = \frac{(NPV_{1,\text{up}} + 0)/2}{1.05} = \frac{0.31}{1.05} = \$0.295.
  \]

We now conclude:

- Buying the mine has positive NPV.

- We should not extract now, but wait for one year:
  - If the copper price goes up, we extract.
  - If the copper price goes down, we do not extract.

- The NPV is \((0.295)(1,000,000) = \$295,000\).
2.3 Lessons from Example 1

- The static naive NPV criterion considers only the possibility of either accepting or rejecting the project at \( t = 0 \). It *ignores* possibility of postponing this decision to next period, \( t = 1 \).

- Even if we consider the possibility of waiting using naive NPV calculations, it *ignores* the value of the option to take different actions using new information.

- As long as there is some uncertainty about the future price, the value of the option to postpone the decision to invest is valuable and should be taken into account.

  - In Example 1, the value of the option to postpone the production decision is given by the difference between the static and dynamic NPVs
    
    \[
    \text{Value of Waiting} = 0.295 - 0.200 = 0.095.
    \]

  - This difference in value comes from the option to take advantage of the additional knowledge learned later, in deciding whether or not to undertake the project.

- NPV rule is still correct when applied correctly.
3 Valuation of Strategic Options

3.1 Option to Wait

The project described in the previous example is very similar to an American call option.

- UW has the right to ‘exercise’ (undertake) the project by paying the ‘strike price’ (the extraction cost), now or later.
- The payoff to the project depends on future copper prices.
- Wait to exercise option optimally.
- Value of the option:

\[ NPV_0 = \frac{(0.5)(2.6 - 1.98)(0.5) + (0.5)(0)}{1.05} = 0.295. \]
3.2 Options to Undertake Follow-up Projects

Example 2. In 1990, MC Inc. considers entering PC business:

- R&D has come up with model-A — a new PC model
- CFs of model-A, if introduced, are as follows

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<thead>
<tr>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Investment ($M)</td>
<td>-450</td>
<td>-50</td>
<td>-100</td>
<td>-100</td>
<td>125</td>
<td>125</td>
</tr>
<tr>
<td>(R&amp;D, plant, WC)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operating CF ($M)</td>
<td>140</td>
<td>159</td>
<td>259</td>
<td>185</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Net CF</td>
<td>-450</td>
<td>90</td>
<td>59</td>
<td>159</td>
<td>310</td>
<td>125</td>
</tr>
</tbody>
</table>

NPV at 20% is -$46 million.

- Development and production of model-A would allow MC Inc. to introduce model-B in 1993.
- Expected CFs from model-B are twice that of model-A.
- In expectation, model-B is a loser too.
- But there are scenarios in which model-B really pays off.

<table>
<thead>
<tr>
<th>Different Scenarios</th>
<th>PV of model-B ($M)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benchmark scenario</td>
<td>-92</td>
</tr>
<tr>
<td>Initial Investment reduced by 30%</td>
<td>178</td>
</tr>
<tr>
<td>Sales increase by 40%</td>
<td>368</td>
</tr>
<tr>
<td>Profit margin increases by 50%</td>
<td>302</td>
</tr>
</tbody>
</table>

Question: Should MC Inc. start model-A?
The expected value of model-B is -$92 million. Could this prospect justify the $46 million sacrifice to enter the market with model-A? Suppose that distribution of possible NPV of model-B in 1993 is as follows:

Note:

- Starting model-B in 1993 is an option.
- So long as MC can abandon the business in 1993, only the right-hand-side of the distribution is relevant.
- The NPV of the right-hand-side is huge even if the chance of ending up there is less than 50%.
Assume:

- Model-B decision has to be made in 1993
- Entry in 1993 with Model-A is prohibitively expensive
- MC has the option to stop in 1993 (possible loss limited)
- Investment needed for model-B is $900M (twice that of A)
- PV of operating profits from model-B is $468 million in 1990
- PV evolves with annual standard deviation of 35%.

The opportunity to invest in model-B is like a 3-year call option on an asset worth $468 million now with exercise price $900 million!

Using Black-Scholes formula:

\[ \text{Value of Call} = 55 \text{ million} \]

Total NPV of model-A ($M):

\[
\begin{array}{ccc}
\text{DCF} & \text{A} & \text{A+B} \\
\text{Option value} & 55 & 99 \\
\text{Total value} & 55 & 9 \\
\end{array}
\]
4 Comments on Strategic Options

1. Naive DCF analysis tends to under-estimate the value of strategic options:

   - Timing of projects is an option (American call)
   - Follow-on projects are options (American call)
   - Termination of projects are options (American put)
   - Expansion or contraction of production are options (conversion options).

2. It is difficult to apply DCF for option valuation.

3. Options can be valued (sometimes).

It is important to think of strategic planning as a process of

1. Acquiring and disposing of options

2. Exercising options optimally.
5 Homework

Readings:

- BMA Chapter 22.